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Study on the rapid detection of irradiated rice based on RVA

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Abstract In this paper, the changes of rice-starch's viscosity at different dose irradiation treatment were studied, the rice can be easily distinguished whether it has been irradiated or not with the control of pH. The results showed that the starch's viscosity was significantly declined with increasing irradiation absorb dose. With the control of pH 2.5, the irradiated starch's viscosity was apparently higher than the un-irradiated ones, there are significant differences in terms of viscosity between the two parts. The rice absorbed dose can be estimated using the relationship among peak viscosity, hot pasting viscosity and absorbed dose.

Key words Starch, Irradiation, RVA diagram, Detection

1 Introduction

The processing of irradiating food involves controlled application of energy from ionizing radiations such as gamma rays, X-rays, and electron beam has recently become one of the convenient and efficient methods to preserves food[1,2]. Based on the physical, chemical, biological, and microbiological changes in food products during irradiation, the minimal changes can be detected to determine whether the food has been irradiated or not[3]. During 1996, the European Committee for Standardization (CEN) adopted 5 European standards for detection of irradiation process in food commodities, EN-1784 to EN-1788, and in 2004, 5 more validated standard methods, EN-13783, EN-1384, EN-14596, EN-13708, and EN-13751 came in to existence[4,5].

Rice is one of the major cereals, and its main component is starch consisting of amylose and amyl pectin[6]. The way for rice storage is closely related to the food safety and people's health. The purpose of keeping rice fresh technique is to protect them from insect infestation and microbial contamination during storage, processing, market circulation and consuming. Gamma irradiation is an economical and effective way to preserve rice toward desinsection because of its high penetrating power and thorough insecticide, hence, it is capable of killing the worm eggs inside the grain of rice, and there is no smell or residual toxicity left after irradiation, so it gets increasing attention from the people[8].

At present, the detection for the irradiated food is being studied in China now, but no uniform standard has been formed yet, in addition, there is no technique that can applied to all the food detection. A few reports focus on the distinction of the irradiated food or the estimation of the irradiated dose[9,10]. In this paper, we choose starch in the rice (round-shaped rice) as our research goal. The viscosity changes at different dosage after irradiation was investigated. In this method, the reference samples are not needed.

2 Materials and methods

2.1 Samples source

All of the studied samples are purchased from the local supermarket, which belongs to the late round-shaped rice, the name of the samples are not in detailed. The samples are sealed in polythene (PE) bag, there are nine bags, and each bag is amount to 50 g.

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2.2 Irradiation treatment

The starch samples are exposed to ^{60}Co source at an ambient temperature at the Irradiation Center, Zhejiang University, Hangzhou, China. Nine doses of irradiations, i.e. 0, 0.1, 0.3, 0.5, 0.9, 1, 3, 5 and 7 kGy were used with the dose rate of 0.8 kGy/h.

2.3 Analysis of starch's viscosity

The samples are ground into powders，and then pass through a sieve of 100 mesh size. The starch viscosity was determined in duplicate by a Rapid Visco Analyser (RVA, Model-3D, Newport Scientific Inc, Australian), which was controlled by a computer software, the Thermo Cycle for Windows (TCW) (American Association of Cereal Chemists (AACC), 1998)[3]. When the moisture content is 14%, the starch is 3.0 g, 25 mL distilled water was added, temperature inside the pot changes while stirring is as follows: The temperature was first maintained in 50ºC for 1 min, then raised to 95ºC at the rate of 12ºC /min, the samples were maintain at 95ºC for 2.5 min, then cooled to 50ºC, after that, the samples were maintained at 50ºC for 1.4 min. The paddle will rotate at 960 rpm for the first 10 s, then at 160 rpm for the reminder of the test. The viscosity value can be expressed as Rapid Visco Units (RVU), the following parameters, peak viscosity (PV), hot viscosity (HV), cool viscosity (CV), break down (PV minus HV) and set back (CB minus PV) were used as the characteristic value of the RVU profile.

2.4 Detection method

Two parallel samples were selected from the starch samples without gelatinization, one was added acid solution pH 2.5, the other was added distilled water (blank experiment), the samples all were stirred to uniformity at the same conditions, the viscosity of the starch was tested on the Rapid Visco Analyser, the dynamic changes of the RVA profile was monitored. The samples were determined to be irradiated if the RVA profile is higher at pH 2.5 compared to the samples added distilled water. The samples were determined to be free from irradiation treatment if the RVA profile is lower at pH 2.5 than the samples added distilled water.

3 Results and analysis

3.1 Irradiation effect on the starch's viscosity at different doses

The PV, HV and CV were considerably decreased with increased dose when the starch was irradiated at different dose, as shown in Fig.1, but it did not show obvious regularity.

The parameters for the starch viscosity declining can be serving as the reference whether the samples have been irradiated or not. Some reports think that starch degradation reaction resulting in the decline of the molecular weight is responsible for the decrease of starch's viscosity when the amylase and amyl pectin was irradiated. Others held the view that high dose irradiation, which brings about the changes of its physicochemical properties, such as the decrease of its optical rotation and the changes of its optical prosperities and granule structure, can cause the cleaving of polysaccharide chains, thereby generating degradable fragments of dextrin, and that is the key reason for the decrease of starch content[11,12].

3.2 pH effect on the RVA profile

According to the method describe in 2.4, the samples are equally separated into two parts, one part was added distilled water (pH 7), the other was added acid solution (pH 2.5), the RVA profile can be obtained on the Rapid Visco Analyser. For the un-irradiated rice, we can discover from Fig.1 that the starch viscosity is higher at pH 2.5 than pH 7, However, the starch viscosity of irradiated ones is lower at pH7 than at pH 2.5, which is still less than the viscosity of un-irradiated counterparts. The higher of the irradiation dose is, the lower viscosity is, the lower viscosity is. The results above can be explained that hydrogen ion can coalesce small polysaccharide chains caused by irradiation and cleavage into larger molecules, as a result, the molecular weight increasing compensates for the viscosity[13]. Hence, with the control of pH which can markedly alter the RVA performance, we can quickly evaluate whether the starch (round-shaped rice) has been exposure to irradiation treatment or not.

3.3 Relationship between viscosity and irradiation dosages

According to the data displayed in Table 1, with the regularity between PKV, HPV, CPV and irradiation dosages, the viscosity value was considered as the ordinate, and the absorbed dosage was takes as the abscissa, the logarithm of viscosity (Y) exhibits exponential correlation with absorbed dosage (D) after exponential fitting. The absorbed dosage can be calculated. We can discover from Table 2 that the theoretically calculated value is far from the actual irradiation dose when the irradiation range is 0–0.1 kGy. The negative number represents two cases, one is un-irradiated, and the other is the case that the estimated absorbed dosage is less than the actual absorbed dosage. In actual practice, we should distinguish if the samples are irradiated, if the RVA value is higher at acid conditions than at neutral conditions, then the samples has been exposure to irradiation treatment. On contrast, if the RVA profile is higher at neutral conditions than at acid conditions, then the samples are not irradiated[14].

Table 1 Relationship between viscosity and dose

Dos/ kGy	Peak viscosity	Hot viscosity	Cool viscosity	Break down	Set back	Pasting time
ck	140.83	87	146.67	53.83	5.83	6.27
0.1	112.25	83.17	138.00	49.08	5.75	6.2
0.3	106.58	77.17	106.83	26.25	5.58	6.4
0.5	95.08	65	90.33	30.08	–8.25	6.73
0.7	89.42	55.92	86.83	33.5	–9.5	6.6
0.9	84.75	58.5	79.92	29.42	0.25	6.8
1	81.17	38.08	78.5	36.58	3.83	6.07
3	78.75	35.92	72.75	45.25	–8.42	5.93
5	74.67	33.17	68.33	45.58	–10.42	5.8
7	50.75	16.08	44.83	34.67	–5.92	5.33

Table 2 Relationship between viscosity and irradiation dosage

D/kGy	PKV $y=2.0324e^{-0.032x}$, $R^2=0.9062$			HPV $y=1.874e^{-0.064x}$, $R^2=0.9703$			CPV $y=2.0504e^{-0.046}x$, $R^2=0.9212$		
	Lg(RVU)	Destimate/kGy	Relative error/%	Lg(RVU)	Destimate/kGy	Relative error/%	Lg(RVU)	Destimate/kGy	Relative error/%
0	2.15	1.76	100	1.94	0.54	100	2.17	1.23	100
0.1	2.05	0.27	170.00	1.92	0.38	280.00	2.14	0.93	830.00
0.3	2.03	–0.04	86.67	1.89	–0.13	56.66	2.03	–0.22	26.67
0.5	1.98	0.82	64.00	1.81	0.54	8.00	1.96	0.98	96.00
0.7	1.95	1.29	84.29	1.75	1.07	52.86	1.94	1.20	71.43
0.9	1.93	1.62	80.00	1.71	1.43	58.89	1.9	1.66	84.44
1	1.91	1.94	94.00	1.69	1.61	61.00	1.89	1.77	77.00
3	1.83	–3.28	9.33	1.53	3.17	5.67	1.77	3.20	6.67
5	1.74	–4.85	3.00	1.37	–4.89	2.20	1.63	–4.99	0.20
7	1.64	–6.70	4.29	1.21	–6.84	2.29	1.51	–6.65	5.00

4 Discussion

4.1 Mechanism for the starch viscosity decrease caused by irradiation

The starch in the round-shaped rice consists of amylose and amylopectin, and amylose is commonly called chain starch, chain starch is composed of *D*-anhydroglucose units linked by α-1,4 glycosidic bond, amylopectin is composed of D-anhydroglucose units connected by α-1,6 glycosidic bond and α-1,4 glycosidic bond, and the branch positioned in the α-1, 6 glycosidic bond[15,16]. From the analysis of the experiment, We can conclude that the rice viscosity is decreasing with increasing irradiation dose. Owing to the γ ray, irradiation was capable of degrading starch through the cleavage of glycosidic linkages and peptide bonds into smaller fragments, such as peptide derivatives of short aldehyde, ketone, acid chain and monosaccharide (glucose, maltose, dextrin) as well as amino acid and some small molecular weight fragments, then the starch viscosity was declined[16,17].

Water in the samples can generate free radicals and hydrated electron free radicals, these radicals can react with the group in the glycosidic bond and peptide as well as the radicals generated by protein after irradiation. The fact that the starch can further cleaved into glycosidic bond and peptide chain through just one chain reaction can possibly accelerate the viscosity decrease[18]. The H radicals in the water can also react with the group on the aldehyde、ketone, acid, leading to the polymerization of the short chains, which can compensate for the starch viscosity to some degree, as shown in Fig.1.

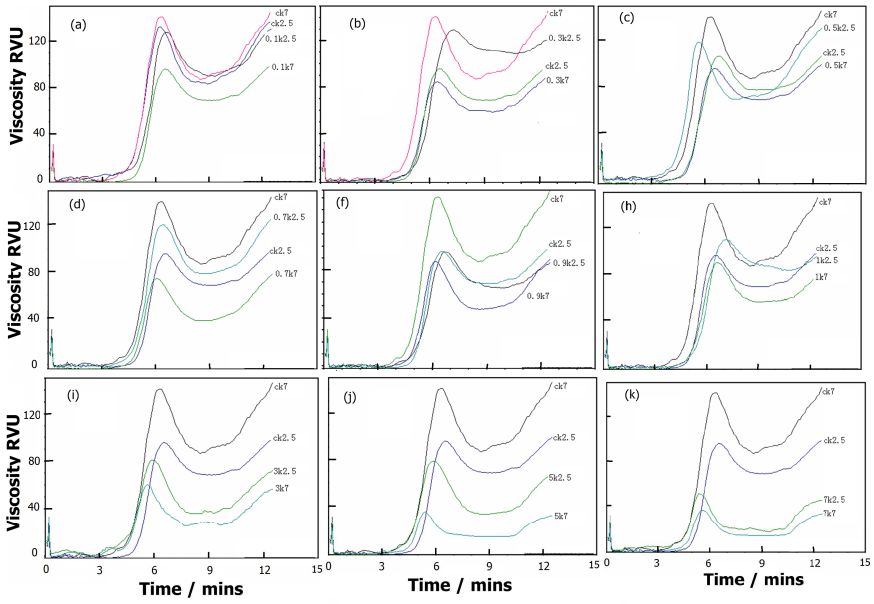

Fig.1 Starch viscosity (RVU) change after irradiation.

4.2 Error analysis for the estimated irradiation dosage

When the data in Table 2 was analyzed, we find that the theoretically calculated value is far from the actual irradiation dose when the irradiation range is 0.1–1 kGy, but the error is relatively small with the irradiation range is 3–7 kGy (0.2–9.33%), especially the relative error at 7 kGy between theoretically calculated value and actual irradiation dose is within 2.5%. The main reasons for the error can be described as follows: (1) the error caused by irradiation, the irradiation dose designed in the experiment is not accordance with the sample's irradiation dose carried in the actual irradiation field, since the sample has certain volume instead of the dose just on one dot. The theoretical calculation is based on the following formula $D=(A\times\Gamma\times T)/R^2$, from which we can obtain the result showing the irradiation volume concentrated on one dot in the air. There is a 0.873×10^{-3} Gy difference between the samples absorbed volume and the irradiation volume in the air. The static irradiation processes are chosen then the sample is being treated, the inaccuracy of the actual distance between the samples and the irradiation source compared to the calculated distance can also cause error. (3) Its necessary to correct the radioactivity of the irradiation source immediately when the samples are being irradiated and we should make sure that the samples being irradiated should maintain on the same horizontal level with the irradiation source. (4) The error caused by sampling time for detection samples irradiation dose is different if the sampling time differs, such as one hour sooner or later. (5) The system error caused by the measurement of the sample viscosity. All of these can bring about the error between theory and practice. Based on the analysis of the experimental data, the lower of the irradiation dose, the higher of the irradiation dose is, the larger the error will be, the lower the irradiation dose is, the higher of the irradiation dose is , the smaller the error will be. It was suggested that the irradiation dose should not be less than 1 kGy when the viscosity was used for verifying the dose, and the result was convincing to some degree. The chemical dosimeter should be placed in the packing bag to track the dose when the samples are

being irradiated, the samples actual absorbed dose is measured.

In the actual process of irradiation operation, the intensity of the ^{60}Co source, the dose heterogeneity of the dosage field, the value of the dose rate, the heterogeneity of the irradiation treatment toward the samples, the uncertainty of the selected sample and the environmental factors as well as the systematic error all can affect the irradiation performance and the detection results. This research provides a method for the estimation of the irradiated dose, and this method can be served as a reference for the related research.

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